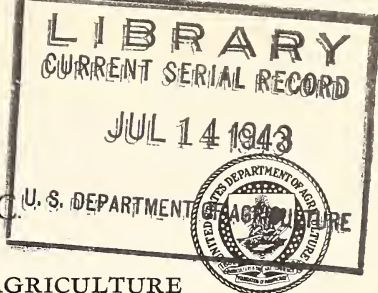


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Dutch Elm Disease and Its Control

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INTRODUCTION

In the northeastern part of the United States and other localities a large proportion of the trees that are important in camouflaging cities, factories, military structures, and highways are elms. All feasible steps should be taken to protect and maintain these trees in health. In the Northeast, Dutch elm disease, which was evidently brought to this country from Europe between 1920 and 1930, is at present the principal threat to the well-being of the elms.

Because of the war the Federal control program is being directed toward preventing the expansion of the infected areas and destroying the Dutch elm disease in isolated areas. More and more, private owners of elms must protect their own trees and carry out the sanitation measures necessary to restrict the disease. To furnish owners and managers of elm-concealed factories, estates, and valuable installations with the necessary information concerning the disease and its insect carrier is the object of this circular.

SYMPTOMS

Dutch elm disease is a wilt (fig. 1), which in its mildest form reduces the protective value of the foliage and also the rate of growth of the tree. The effects of the disease range from very slight dwarf-

ing of leaves, through yellowing and various degrees of defoliation (fig. 2), to death of the entire tree or parts of the tree (fig. 3). The disease is usually more acute on succulent, rapidly growing trees than on either slowly growing or senile trees. The water-conducting tubes of diseased trees are discolored and obstructed by brown gummy substances (fig. 4). In Europe diagnosis from symptoms is practicable. But in the United States neither the internal symptoms nor the foliage effects are sufficiently distinct from those of two native diseases of lesser importance to allow field diagnosis of the Dutch elm disease. For accurate diagnosis a laboratory test must be made by competent authority. During the present emergency owners should remove all beetle-infested wood. This will reduce the beetle population and the spread of the Dutch elm disease.

CAUSE

The disease is caused by a fungus known as *Ceratostomella ulmi* Buisman. Studies by mycologists in the Netherlands, Germany, and the United States have provided detailed information concerning its life history. Within the water tubes of the infected but living elm the fungus is almost entirely in a yeastlike stage. Its spores increase by budding and are known to be distributed rapidly within the individual water tube by the movements of the sap.

Soon after the host tissues die, the fungus grows through the wood as a saprophyte and produces spores abundantly on the inner surface of the bark and outer surface of the wood. Only the asexual fruiting stages have been found in the United States. In England and western Europe both asexual and sexual (perithecial) fruiting stages are common. All stages of the fungus are infectious, and all are too small, except in mass, to be recognized by the unaided eye.



FIGURE 1.—Wilted leaves and tender twig tip of American elm. The dry, brown tuft of leaves on the end of the "shepherd's crook" frequently persists through the winter long after the large wilted leaves, which finally turn brown, have fallen. Natural size.

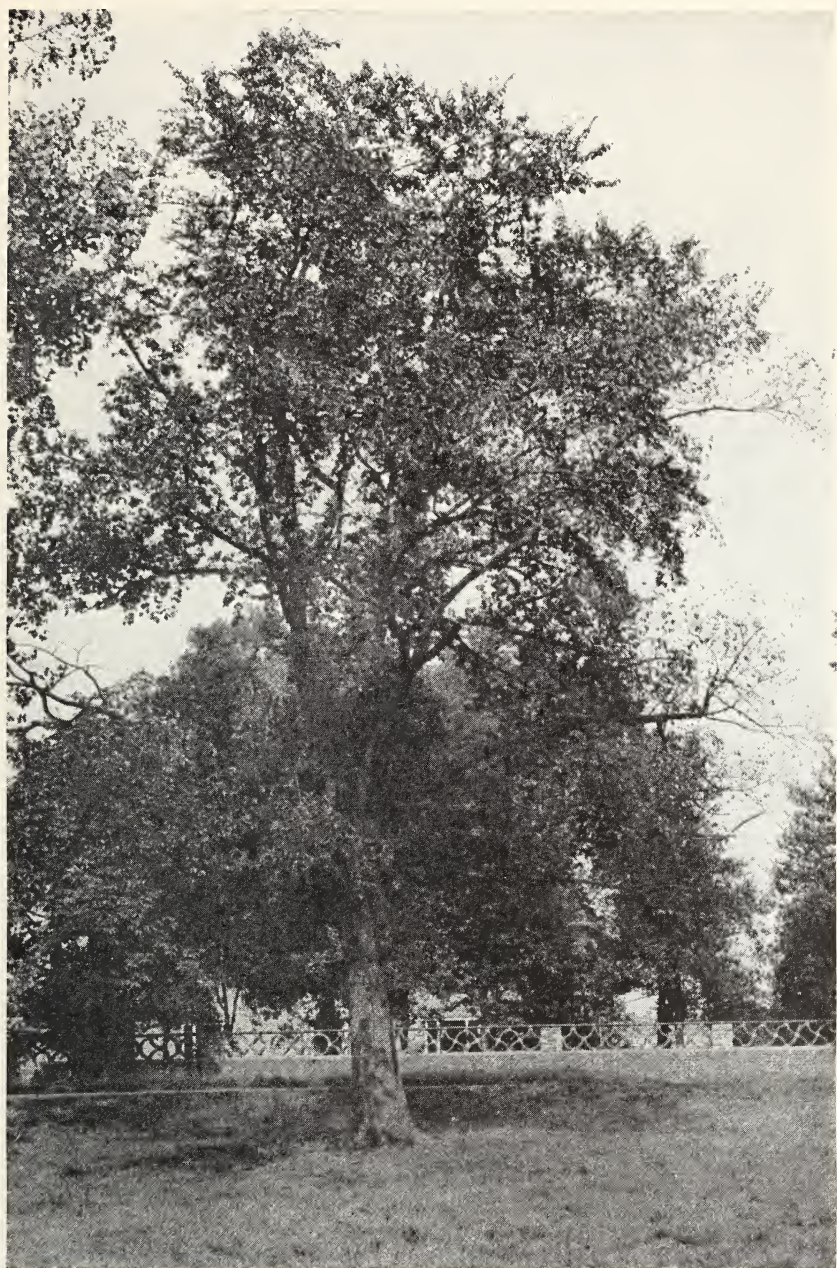


FIGURE 2.—A 50-foot English elm with symptoms of wilt and defoliation limited to a few branches. In cases where localized symptoms develop in late summer, pruning the diseased branches is sometimes an effective control measure.



FIGURE 3.—A wilting and partly defoliated 30-foot American elm severely affected with Dutch elm disease. An elm in this condition is likely to be attacked by bark beetles. Pruning such a severely affected tree is not advised.

FIGURE 4.—Cross section of a young branch of American elm showing typical discoloration due to the disease in the most recently formed ring of large, spring water-conducting vessels.

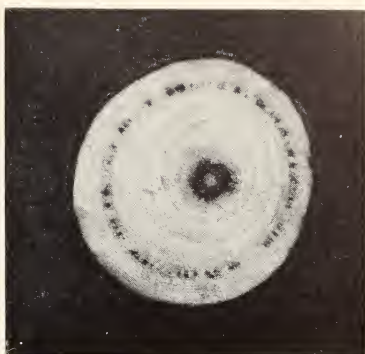


FIGURE 5.—An adult beetle of *Scolytus multistriatus* feeding in an elm twig crotch. During feeding it may deposit spores in the feeding injury; these spores can invade the tree and cause disease. Four times natural size.

FIGURE 6.—*A*, Injury in the crotch of an elm twig made by the feeding of *Scolytus multistriatus*. One and one-third times natural size. *B*, Brood galleries made by female beetles and larvae. One-fifth natural size.



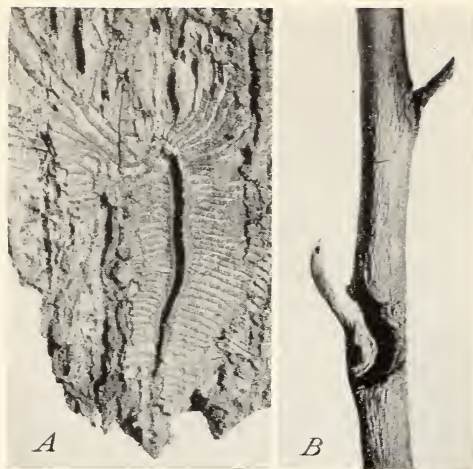


FIGURE 7.—A, Inner bark showing galleries made by female beetles and larvae of *Scolytus scolytus*. B, Feeding injuries in crotches of twigs. Two-thirds natural size.

TRANSMISSION

The fungus causing the disease is transmitted from elm to elm by the feeding and reproductive activities of bark beetles belonging to the family Scolytidae; their habits admirably adapt them for contacting the spores of the fungus and then placing them in position to start new infections. The fungus and insect are each favored by the action of the other. In the United States the important carriers are the introduced smaller European elm bark beetle (*Scolytus multistriatus* (Marsh.)) and the native elm bark beetle (*Hylurgopinus rufipes* (Eichh.)). In Europe the former is an important carrier, but its work is overshadowed by that of the larger and more voracious *Scolytus scolytus* Fab. The adults of the two species of *Scolytus* chew into small branches or twigs, commonly at crotches (fig. 5). When the feeding injuries are made to the depth of the current season's water tubes (figs. 6 and 7) they are fairly effective places for the fungus to get into the tree.

Scolytus beetles develop from egg to adult in the same portions of the dying and dead elm in which the fungus produces its spores. In fact, the channels and chambers (figs. 6 and 7) cut by the beetles are frequently the best places to find the fruiting structures of the fungus. The beetles carry the fungus to broken limbs still hanging in the tree, and also to much fallen and cut elm, suitable for their breeding, that may never have had the Dutch elm disease. In such wood the fungus proceeds to develop as a saprophyte, commonly producing its spores in time to contaminate the beetles (fig. 8) of the new generation before they emerge and feed on growing elms.

Elms that have wilted or suffered severe water shortage because of the disease are attractive to the beetles when they are ready to con-

struct their brood galleries. Many trees, especially of moderately resistant varieties, would no doubt survive severe attacks of the disease if these were not followed shortly by the complications of drilling by bark beetles constructing their brood galleries and of channeling by young larvae in the cambium region.

The large majority of the beetles developing at a given point will fly no farther than necessary to reach elms suitable for their feeding and construction of brood galleries. In localities where elms are numerous and nothing has been done to disturb natural activities of the fungus and the insect, a sharp zonation of diseased trees around bark-beetle sources commonly is found. In other words, the diseased trees occur in groups or centers (fig. 9). How far the bark beetles may fly when aided by winds is not known, but in many cases they have certainly carried the fungus more than 2 miles into new territory and accounted for the establishment of new centers of the disease. Such dispersion results from the habit of the beetles of traversing longer distances for the purpose of breeding than for crotch feeding. Feeding usually takes place relatively near or within a few hundred feet of the points of emergence.

The native elm bark beetle overwinters to some extent in the larval stage, like the members of the genus *Scolytus*; but, in significant contrast, most of the adults of this native beetle construct overwintering cells in the bark of healthy elms. Before the adults emerge in the spring they frequently chew inward from their hibernation cells in the bark until they have contacted the wood. Some trees are infected through this activity of the beetles, which provides a means for survival of the fungus for many years, perhaps indefinitely. However, the native elm bark beetle is a less effective carrier of the Dutch elm disease fungus than *Scolytus multistriatus*. In localities such as

FIGURE 8.—Pupa of *Scolytus multistriatus*, 17 times natural size. Note the small structures (coremia, bearing spores of the Dutch elm disease fungus) growing from the sides of the pupal chamber and touching the pupa. Before it emerges from the pupal chamber the beetle moves its legs and other appendages and thus picks up spores, which it may carry to healthy elms on which it feeds.



Indianapolis, Ind., where the smaller European elm bark beetle formerly was not present, the disease did not intensify so rapidly as in areas in which both species are present.

Although bark beetles are the more important means of transmission, the disease can spread through underground connections between trees. The infection can pass readily from one tree to another by way of both root grafts (fig. 10) and the direct connections of trees that have originated as root sprouts, which are common in dense stands of elms.

After 20 years of experimentation no important method of spread of the disease other than by bark beetles and root connections is yet known.

REACTIONS OF IMPORTANT ELM SPECIES AND VARIETIES

All species and varieties of elm native to North America have proved susceptible to the disease in comparison with some types native to Europe (fig. 11) and Asia. However, by inoculating thousands of American elm seedlings during the last few years, it has been found that an occasional tree within this most susceptible and valuable species possesses some degree of resistance, and efforts are being made to select superior types for hybridization with highly resistant stock of the Siberian elm (*Ulmus pumila* L.). Similar tests on seedling populations of the Siberian elm have demonstrated seedling variation in reaction to the disease, but the results clearly mean that the Siberian

FIGURE 9.—Group of trees affected by the Dutch elm disease. Elm bark beetles that had emerged earlier from the log in the foreground may have been instrumental in carrying the disease to the now defoliated trees. Later in the season the elm on the left developed symptoms. The ash in the center is not susceptible to the disease.





FIGURE 10.—Elm tree root-grafted to the stump of a formerly diseased tree. The disease spreads from tree to tree by such root grafts, which are common in elm woods.

elm is to be classed as resistant. The variety *U. pumila* var. *arborea* Litv. and the Chinese elm (*U. parvifolia* Jacq.) are very resistant, but their usefulness is limited by other important considerations.

Ulmus hollandica var. *belgica* (Burgsd.) Rehd., the important dike-holding and general-purpose elm of the Netherlands, is very susceptible. Before 1930 the Dutch started a search for a resistant variety. The Christine Buisman, a seedling selection from *U. carpinifolia* Gleditsch, is the most highly resistant elm type that the Dutch have found thus far. This elm has been under propagation in Europe for only 10 years, and it is not yet possible to estimate its value with respect to characteristics other than resistance to Dutch elm disease as a substitute for the susceptible elms of Europe or the United States. Small numbers of this elm are now under observation in experimental plantings in the United States.

The small-leaved elm of Europe (*Ulmus carpinifolia*) is a highly variable species, and, though it comprises seedlings and clones of all degrees of reaction to the disease, it must be classed as susceptible. The English elm (*U. procera* Salisb.) and the field elm of Europe (*U. laevis* Pall.) are perhaps best classed as moderately susceptible.

The mountain or Wych elm (*Ulmus glabra* Huds.) is susceptible, but it is still used as a stock for many of the highly prized clones planted in Europe. Some of the latter, such as the Wheatley elm (*U. carpinifolia* forma *sarniensis* (Loud.) Rehd.) and the Huntingdon elm (*U. hollandica* var. *vegeta* (Loud.) Rehd.), are very likely deserving of classification as moderately resistant, especially when grown on their own roots.



FIGURE 11.—A group of diseased elms in England. The trees on the left are a type of small-leaved European elm having considerable resistance to the disease. In this area nearly all other elms have been severely affected. Standing trees recently killed by the disease are commonly a source of disease-carrying beetles.

RECOVERY OF DISEASED TREES

Under ordinary circumstances a considerable percentage of the affected trees, even of susceptible species, may be expected to live and outgrow the effects of the disease within a few years if not re-inoculated. In order to have an opportunity to recover they must, of course, escape the attack of bark beetles during the season in which the fungus has caused the reduction in vitality. The smaller the tree, or the more localized the infection, the more likely a tree is to go through a year following the attack without recurrence of symptoms, other factors remaining the same. The fungus usually survives for several years in the infected but overgrown annual ring, and there is evidence that opportunity for the host to recover comes about only because the fungus does not readily grow through dense layers of living wood. In England some severely affected trees have been known to recover following local sanitation against the bark beetles.

CONTROL MEASURES

Sanitation against the bark beetles that spread the fungus is the most effective means of preserving elms from Dutch elm disease. The emergence of broods of bark beetles from all fallen, storm-damaged, cut, or diseased elms should be prevented. Beetles of the overwintering brood emerging during May and June account for the most damaging inoculations. It is essential, therefore, that all infested wood in which beetles have overwintered be burned or de-

barked before May, or be treated by spraying as described in the following paragraph. If the bark is removed, it should be destroyed, because some of the beetles may complete their development in such material.

In some situations, especially where it is desired to save the wood for fuel, infested and noninfested wood may be rendered harmless by spraying. The use of sprays is restricted by low temperatures, the chemicals not being effective at air temperatures below 50° F. The insects must be actively developing for the spray to be effective, and the season for effective application to infested wood in the spring sanitation program coincides with the flowering period of standard varieties of apple (pink to petal fall) or the interval between the breaking of leaf buds and the formation of shoots 3 inches long on American elms of good vigor. Recommended spray formulas follow:

Materials :	Parts by volume
1. Fuel oil (26° to 28° Baumé) -----	12
Monochloronaphthalene -----	1
or	
2. Fuel oil (26° to 28° Baumé) -----	4
Orthodichlorobenzene -----	1

FIGURE 12.—Elm wood in wood piles, fallen trees, or broken limbs still hanging in trees commonly are breeding places for the bark beetles that spread the disease. All beetle-infested wood should be treated as advised on pages 10 and 11.



The same sprays may be used on freshly felled noninfested wood as repellents at any time from May to September. The sprays must be applied in sufficient quantity to cause the bark to glisten, for they must enter the bark through the small holes made by the parent beetles. From $2\frac{1}{2}$ to 3 gallons of spray is required to treat 1 stacked cord of wood effectively.

Some trees that have only one or two branches infected may be freed of infection by pruning, if the symptoms develop quickly and are recognized at once after inoculation. However, chances for removal of the entire infected part without spoiling the appearance of the tree diminish with each day of delay if the infection advances normally through the vascular system.

Pruning for the purpose of eliminating or suppressing the bark beetles will be of more general application. This may be done at any time of the year, but, as stated, it is a good policy to make certain that all branches becoming infested in one season are removed and rendered harmless by burning, spraying, or debarking before May of the next year. Such pruning may be an important feature of a well-conducted sanitation program and appears especially advisable on large, old trees of high value. Pruning only the parts infested by bark beetles will not, for the ordinary case of Dutch elm disease, mean removal of all the wood invaded by the fungus causing the disease. However, after being pruned, such trees should have approximately the same chances of recovery as described for infected trees not attacked by the beetles.

It is sound policy to suspect all elms within 25 feet of a diseased tree and to watch them carefully for several years after the removal of the known case. The reason is the common occurrence of root connections between elms within 25 feet of each other (fig. 10).

Above all, in sanitation against Dutch elm disease it is essential to avoid piling elm wood in the open (fig. 12) unless it is peeled or sprayed with a bark beetle repellent. Time after time it has been noted that local outbreaks of the disease have as their central points small piles of wood that could not have been worth one ten-thousandth of the damage resulting from the fungus and bark beetle carriers incubated by them. It seems clear that piled wood is a more effective source of inoculum than standing dead trees, because the piled wood, especially if some of it is in contact with the soil, maintains a moisture content more favorable for the lush sporulation of the fungus. Any cut elm that is to be used for construction should be sprayed, peeled, or stored under water so that the bark beetles can not reproduce in it.

It is urged that everyone interested in the protection of elms from Dutch elm disease spread this gospel of sanitation. The best level of efficiency in controlling this disease can be attained only if a high standard of sanitation is maintained throughout a community.

